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REPORT NO. NADC-89099-40

COMMUNICATIONS NETWORK ANALYSIS TOOL

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1 NOVEMBER 1989

FINAL REPORT

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Prepared for
NAVAL AIR SYSTEMS COMMAND (PDW-159)
Washington, DC 20361-5000

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SECURITY CLASSIFICATION OF THIS PAGE

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1a. REPORT SECURITY CLASSIFICATION Unclassified	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION / AVAILABILITY OF REPORT Approved for Public Release; Distribution is Unlimited
2b. DECLASSIFICATION / DOWNGRADING SCHEDULE	
4. PERFORMING ORGANIZATION REPORT NUMBER(S) NADC-89099-40	5. MONITORING ORGANIZATION REPORT NUMBER(S)
6a. NAME OF PERFORMING ORGANIZATION Communication and Navigation Technology Department	6b. OFFICE SYMBOL (If applicable) 4045
7a. NAME OF MONITORING ORGANIZATION	
6c. ADDRESS (City, State, and ZIP Code) NAVAL AIR DEVELOPMENT CENTER Warminster, PA 18974-5000	7b. ADDRESS (City, State, and ZIP Code)
8a. NAME OF FUNDING / SPONSORING ORGANIZATION NAVAL AIR SYSTEMS COMMAND	8b. OFFICE SYMBOL (If applicable) PDW-159
9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER	
8c. ADDRESS (City, State, and ZIP Code) Washington, DC 20361-5000	10. SOURCE OF FUNDING NUMBERS

PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO.	WORK UNIT ACCESSION NO.

11. TITLE (Include Security Classification)
Communications Network Analysis Tool

12. PERSONAL AUTHOR(S)
Wayne Phillips and Gary Dunn

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
Final	FROM ______ TO ______	1989 November 1	32

16. SUPPLEMENTARY NOTATION

17. COSATI CODES		
FIELD	GROUP	SUB-GROUP

18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
Capabilities Document; Communication Load Module; Network Model; Graphics Analysis Module; War Game Module

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

The Communications Network Analysis Tool (CNAT) is a set of computer programs that aids in the performance evaluation of a communication system in a real-world scenario. Communication network protocols can be modeled and battle group connectivity can be analyzed in the presence of jamming and the benefit of relay platforms can be studied. The Joint Tactical Information Distribution System (JTIDS) Communication system architecture is currently being modeled, however the computer software is modular enough to allow substitution of new code representative of prospective communication protocols.

20. DISTRIBUTION / AVAILABILITY OF ABSTRACT ☒ UNCLASSIFIED / UNLIMITED ☐ SAME AS RPT. ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION Unclassified
22a. NAME OF RESPONSIBLE INDIVIDUAL Wayne Phillips	22b. TELEPHONE (Include Area Code) 215-441-2269
22c. OFFICE SYMBOL 4045	

DD Form 1473, JUN 86 Previous editions are obsolete. SECURITY CLASSIFICATION OF THIS PAGE

S/N 0102-LF-014-6603 UNCLASSIFIED

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ACRONYMS

CLM – Communication Load Module

CNAT – Communication Network Analysis Tool

EMTM – Event Message Translation Module

GAM – Graphics Analysis Module

J/S – Jamming / Signal

JTIDS – Joint Tactical Information Distribution System

LCM – Link Connectivity Module

NLAM – Network Loading Analysis Module

NPG – Network Participation Group

WGM – War Game Module

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INTRODUCTION

The Communications Network Analysis Tool (CNAT) is a set of computer programs that aids in the performance evaluation of a communication system in a real-world scenario. Communication network protocols can be modeled and battle group connectivity can be analyzed in the presence of jamming and the benefit of relay platforms can be studied. The Joint Tactical Information Distribution System (JTIDS) Communication system architecture is currently being modeled, however the computer software is modular enough to allow substitution of new code representative of prospective communication protocols.

Figure 1 shows the main components of the CNAT software. The core of the software is shown as the War Game Module (WGM). This module accepts a scenario defined by platforms, their sensors, weapon systems, and mission directives. It plays out the scenario for the length of the game time specified. The results are a list of chronological events, such as radar detections, target intercepts, and threat engagements. These events require various information exchanges and update rates between platforms depending on which communication system protocol is currently being modeled.

The next section of the CNAT is known as the Event-Message Translation Module (EMTM). This module maps the War Game events into communication requirements or message types. Message type does not refer to the actual bits of data being transmitted, but instead refers to the numeric label of a message. The rules by which this is preformed depends on an input file containing an event to message type translation matrix designed by the individual implementing the communication system.

The message information file generated by the EMTM is passed on to the Communication Load Module (CLM). It is here that the message types are processed according to the communication network protocols and interchange requirements. Broadcast message types are transmitted to a specific set of platforms depending on the structure of the Network Participation Group (NPG) and the contents of the message types. An NPG is defined to be a community of interest of a given communications function, such as surveillance. The CLM must replicate broadcast message types, creating one message type for each transmitter / receiver pair.

The Link Connectivity Module (LCM) provides an output file that defines the connectivity between platforms at all times during the scenario. Using the connectivity matrices provided by the LCM, links are checked for each message type transmitted. All message records will then contain information indicating whether the receiver could receive the message type taking into account considerations such as line-of-sight, the presence of jammers, and signal strength. A message record is defined to be the file information for each message type transmitted.

Message records are output chronologically and contain such information as transmitter, receiver, message type, send status, time of transmission, NPG number, and link connectivity flags.

Finally, the CLM provides information on network capacity performance. For JTIDS, the network provides a given amount of transmit time for each message transmission function required by a given platform. The CLM reports when an overflow condition exists, i.e. not enough transmit time is available for radar surveillance information. Data is also provided showing the amount of delay that will be introduced into the system by the overload condition present in the network.

The Graphical Analysis Module (GAM) provides a means to quickly analyze the communication system's performance in terms of link connectivity and system loading. Contained in this module are utilities to graphically display the information provided by the above described modules as well as the means of analyzing the connectivity and resistance to jamming of the network immediately after running the WGM.

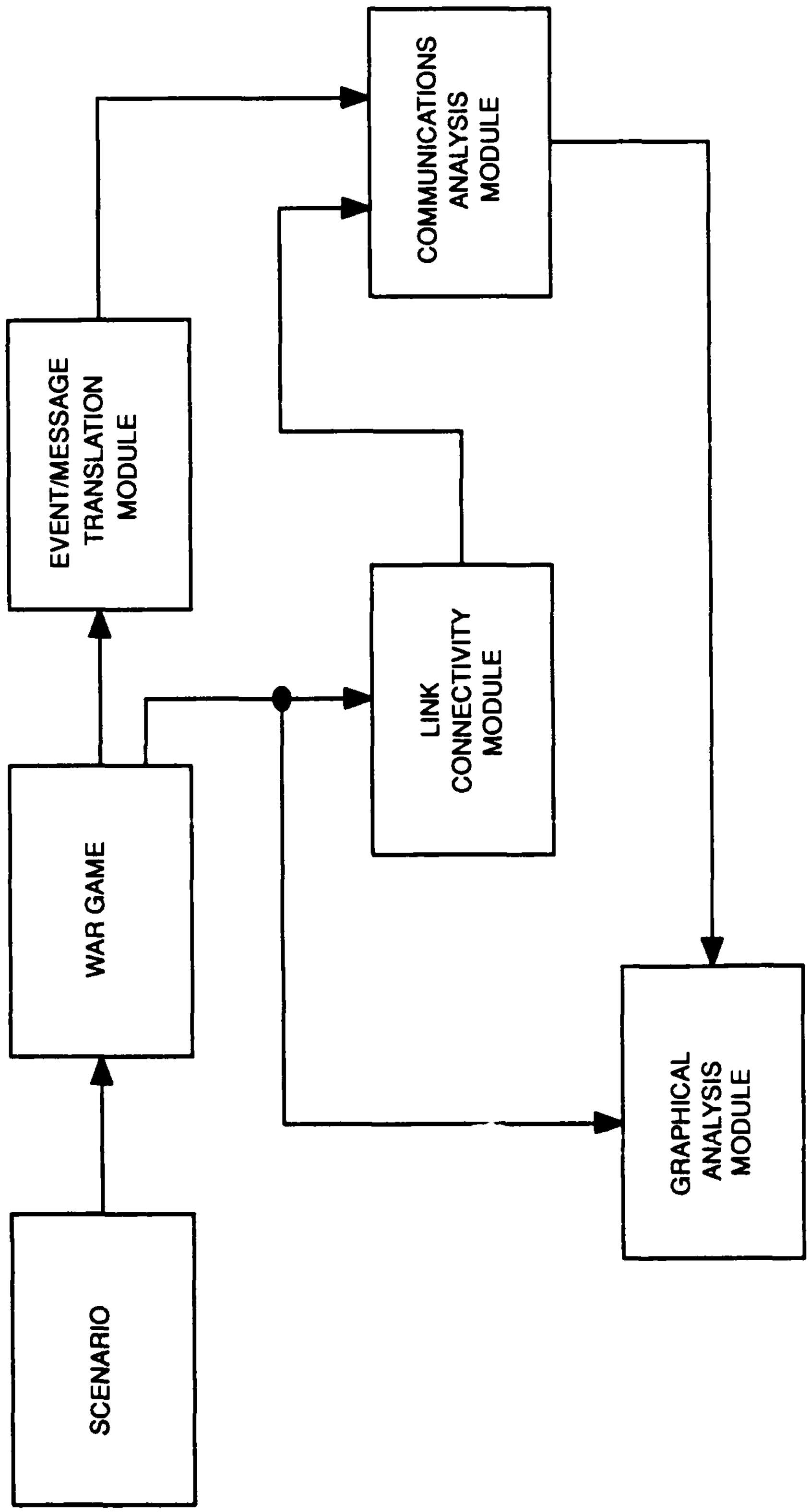


Figure 1. Communications Network Analysis Tool.

SOFTWARE OVERVIEW

WAR GAME MODULF

The WGM is illustrated in Figure 2. This software module takes an input scenario file consisting of platforms, their parameters and movement directives, and plays out all movement directives through the total time specified by the scenario.

Platform parameters include speed of movement, types and number of weapons carried, radar types, and communication equipment used. Movement directives include patrol patterns, attack commands, close-air support, and move-to-destination commands.

The War Game executes the movement directives and resolves any actions taken by either side of the conflict. These actions include radar detections, aircraft vectored for intercept, missiles fired for intercept or attack, and any engagements that occur during the specified game-time. An output file consisting of these actions listed in chronological order is generated by the WGM.

EVENT / MESSAGE TRANSLATION MODULE

The EMTM is shown in Figure 3. This module maps important War Game events into the communications traffic resulting from such events. An example of such an event would be a radar detection of an enemy air group. Such an event would prompt a message to be sent, perhaps from an E-2C to an F-14. A chronological file of such events is output by the WGM of the CNAT.

Information present in the file tells the time the event occurred, the prompter or transmitting platform, and the receiver platform. Currently, JTIDS message types are modeled in accordance with OPSPEC 516.1. Based on the specified reporting rules and JTIDS protocols the events are mapped to message types chronologically.

An output file is generated by the EMTM which identifies the event that prompted the message type, the transmitter, the receiver, the actual message type being sent (addressed or broadcast), and the time of transmission.

LINK CONNECTIVITY MODULE

The LCM provides connectivity status between any two platforms in a scenario. If communication is not possible between two platforms , data flags are provided. The Link Connectivity software can be accessed in two different ways. In the first case, as shown in Figure 4, the link connectivity software reads information from input files, processes the information, and produces an output file. The input files contain all the necessary communications parameters, jammer parameters, and a chronological list of x,y position data for the various platforms during the span of game time. The output file generated is a chronological sequence of connectivity matrices showing for each transmitter–receiver pair whether communication is possible and the reasons why or why not. The criteria setting the relevant data flags are the following;

1) The receiver must be within line–of –sight of the transmitter.
2) The signal level at the receiver must be within the required range.
3) The jammer signal level relative to transmitter signal level at the receiver must not exceed specified hardware performance.

All three of these conditions must hold true for message reception to be possible.

In the second case, as shown in Figure 5, the link connectivity software is accessed in a real-time fashion by the graphics display software. At any time during a scenario connectivity between platforms can be analyzed and the resulting information displayed on a graphics terminal. These displays include the following:

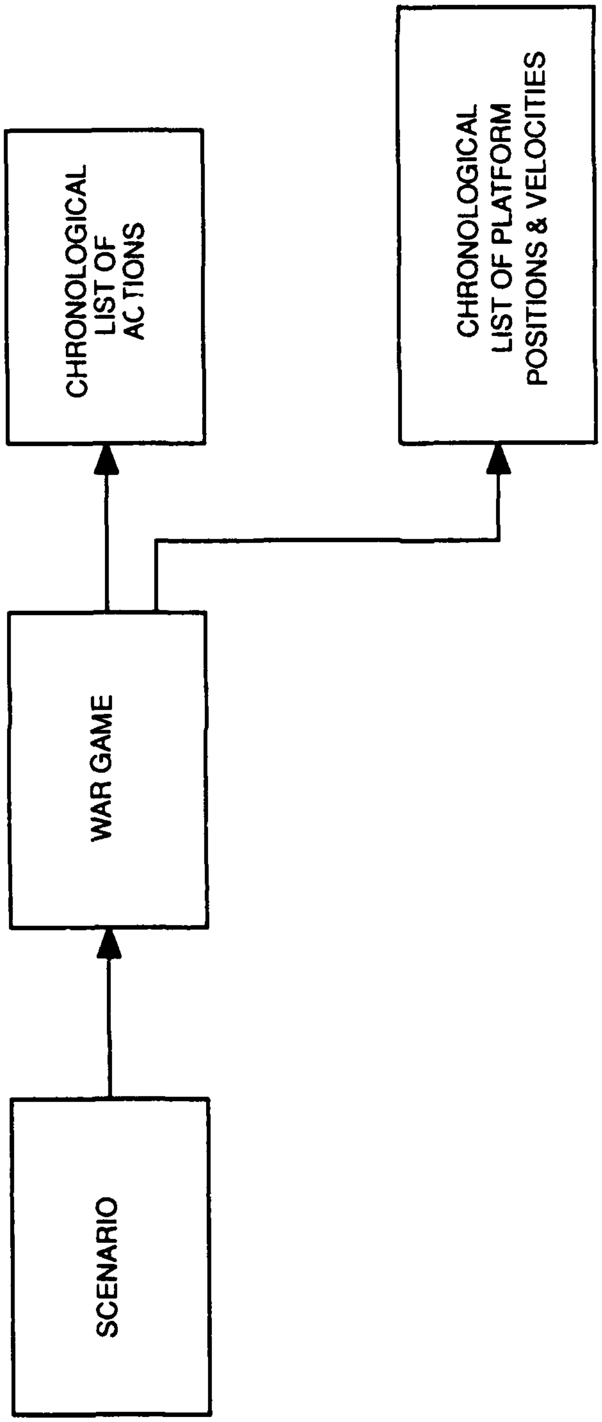


Figure 2. War Game Module.

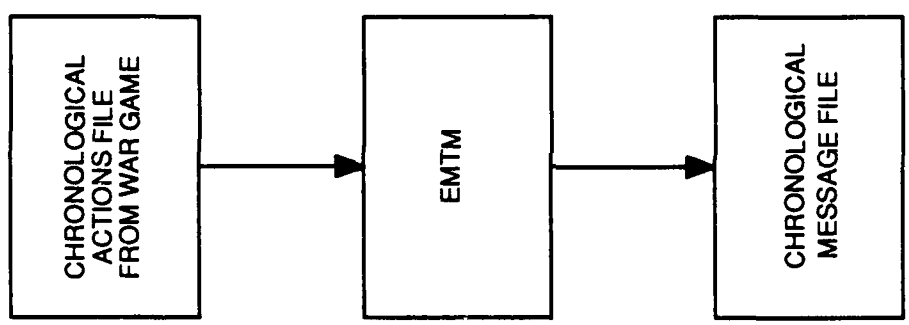


Figure 3. Event-Message Translation Module.

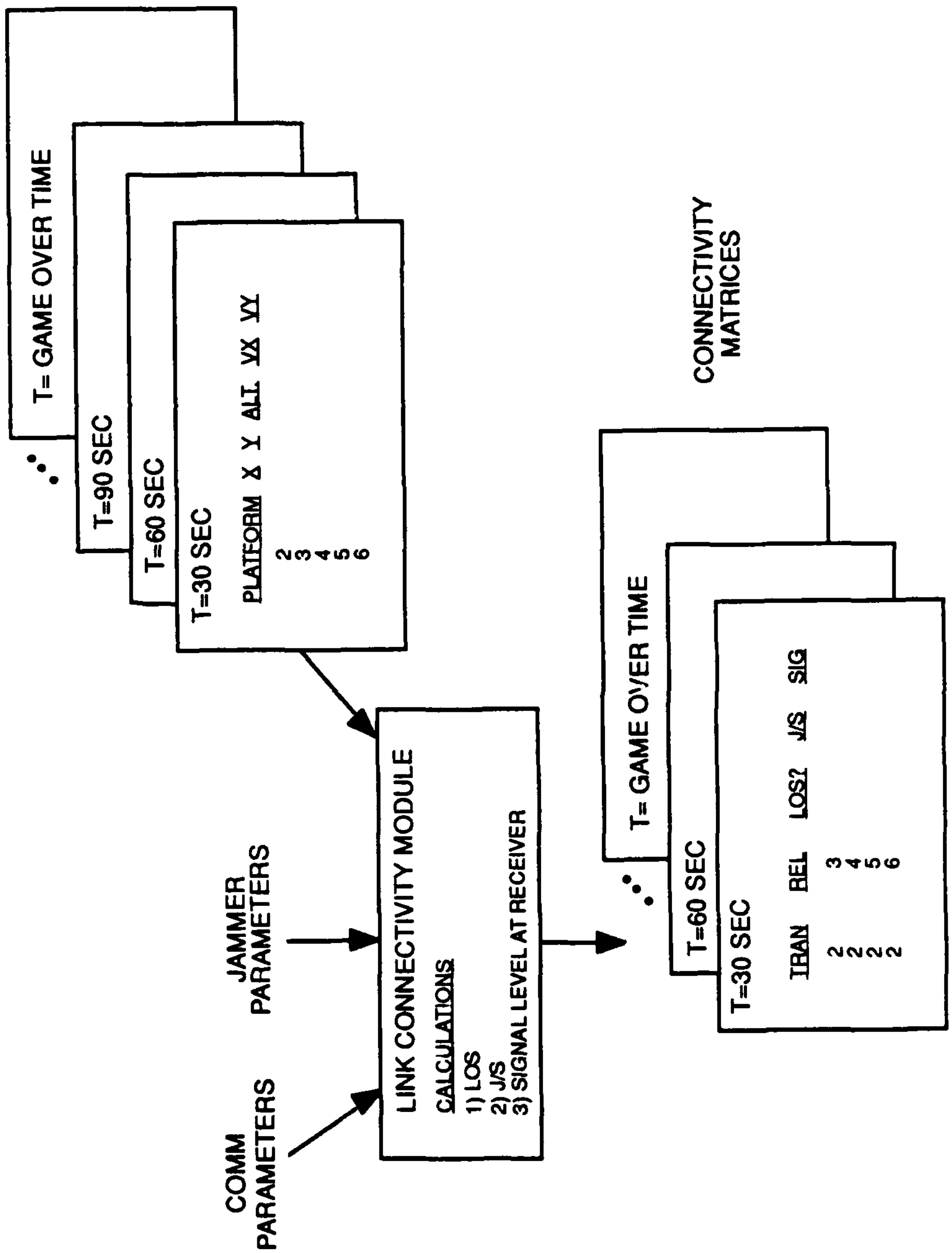


Figure 4. Jamming Model Data Flow.

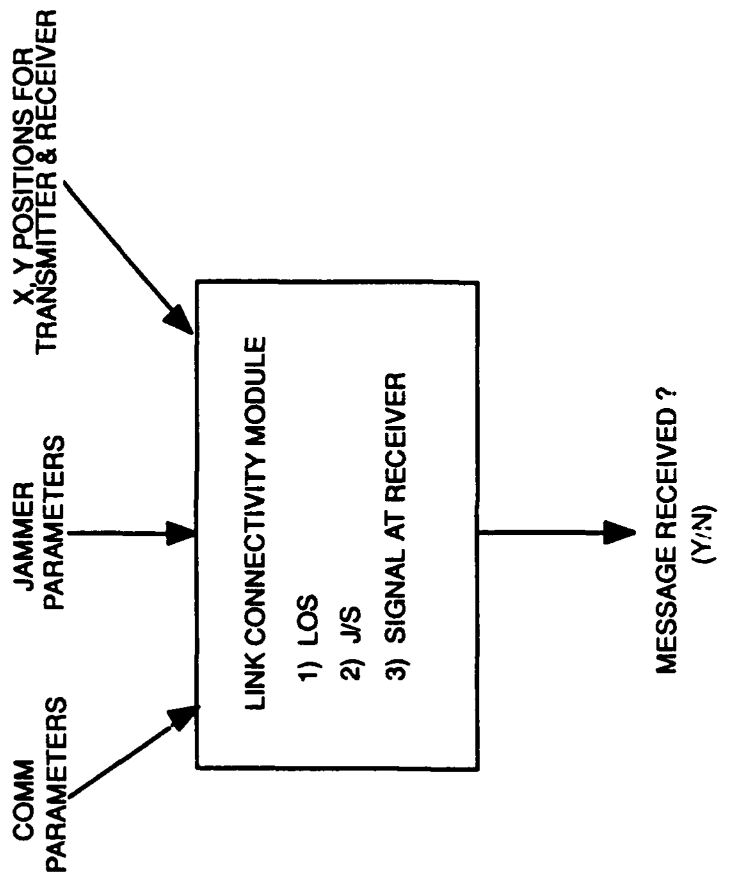


Figure 5. Jamming Model Real-Time Connectivity Processing.

1) Jamming/Signal (J/S) contours around a given transmitter.
2) J/S contours around a given receiver.
3) Color–coded link connectivity lines.

COMMUNICATIONS LOAD MODULE

The CLM takes the message types output from the EMTM, ascertains their network participation group, i.e. who should receive them, and whether or not they physically can be received. This process is illustrated in Figure 6. The message records are arranged chronologically according to message transmission opportunities and message delays are calculated.

Records are kept for all aspects of each message for later analysis. Some of the types of analysis include the following:

1) A dynamic trending display which plots the total number of message types transmitted within a frame that would start at time "X" vs. time in increments of 0.001 hrs.

2) Number of message types transmitted vs. time from starting game time.

3) Number of message types transmitted within a frame vs. time from starting game time.

4) Number of delayed message types transmitted vs. time from starting game time.

5) Number of delayed message types transmitted within a frame vs. time from starting game time.

These are three steps involved in the CLM. The first process reads the message types from the EMTM and determines which NPG they belong to and creates a 'receipt' record for each platform in the NPG that should receive them. The second process checks the appropriate connectivity *matrix* of the LCM output to see if the transmitted message could have been received by the platforms for which it was intended. If not, a relay is attempted, provided that relay capability is specified for platforms of that NPG. Receipt compliance is done, if required, for received message types.

The third process loads the message types into frames determined by slot allocations for NPG or platform. Slot allocations are defined in the csm_tbl_data file. Queues are kept for each NPG or platform when demand exceeds capability and are recorded at the end of each frame. For each new frame, queued message types are considered first.

Before the module can be run, an NPG definition file must be created. The information in this file will be the NPG number, the function of the NPG, i.e. Surveillance, who the participants are in that NPG, and which participants, if any, will have relay capability.

GRAPHICAL ANALYSIS MODULE

The capability present in this module allows the scenario to be viewed as it is played out and at the same time analyze the communication system performance both in real-time and freeze-time modes. These capabilities are shown in Figure 7. Real-time mode, as depicted in Figure 8 displays the platforms as they execute their movement directives visually on a graphics workstation. The following displays can be generated as the scenario is played out on the graphics terminal:

1) Position plot of all platforms as they proceed through their assigned movement directives and interact in the wargame including significant event occurrence plots (i.e. events which produce the need for communications traffic such as radar detections, control of intercept aircraft, ect.).

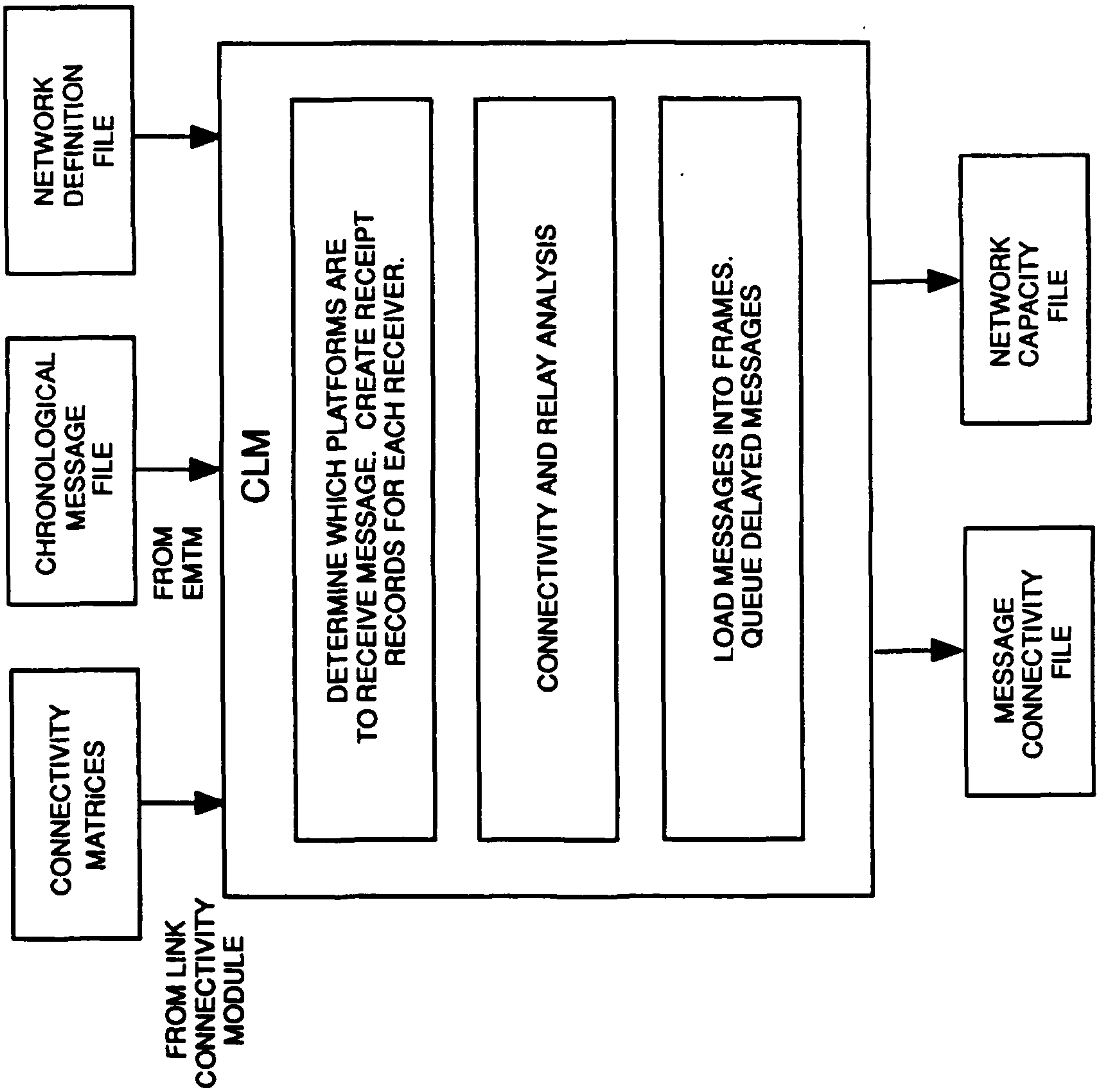
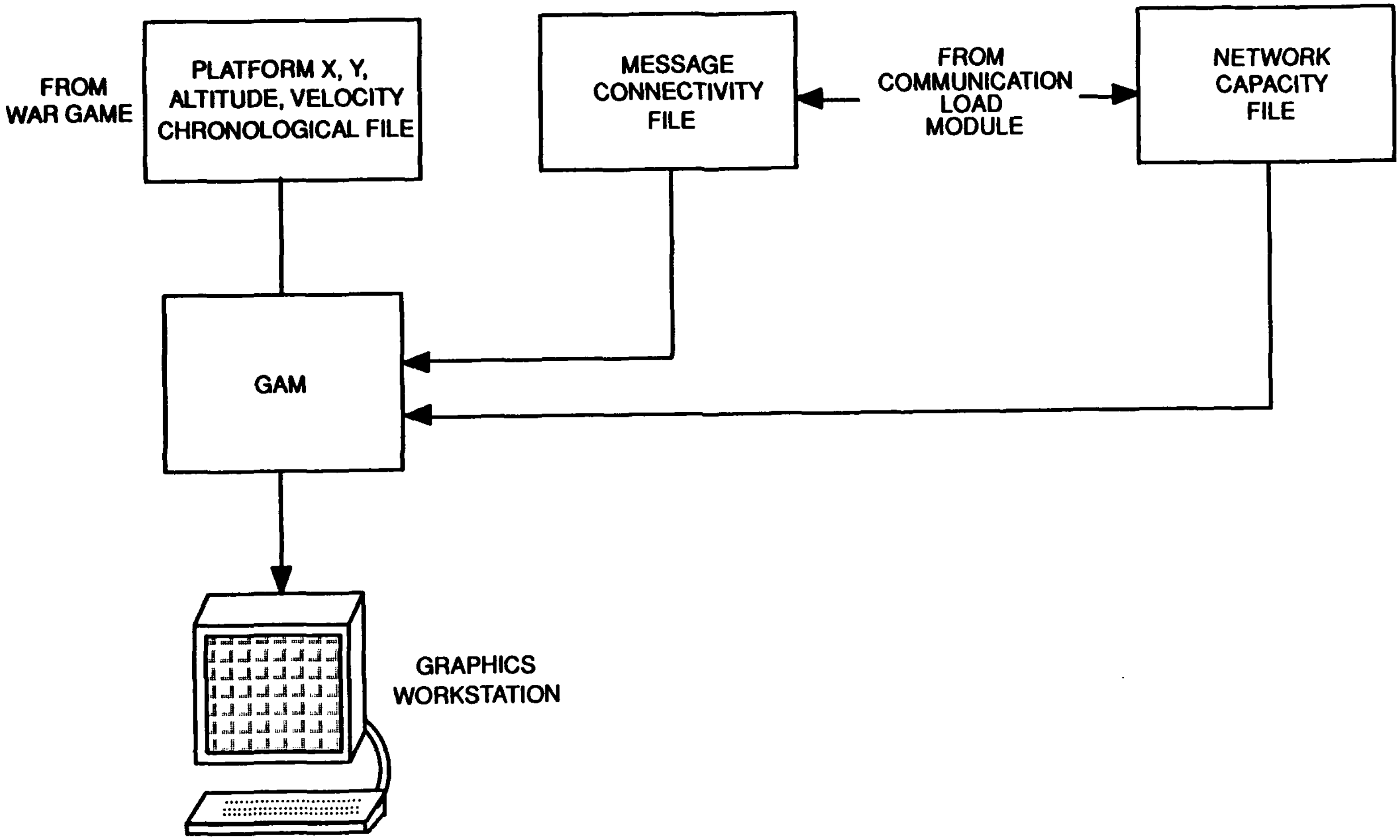


Figure 6. Communications Load Module.



Figre 7. Graphical Analysis Module.

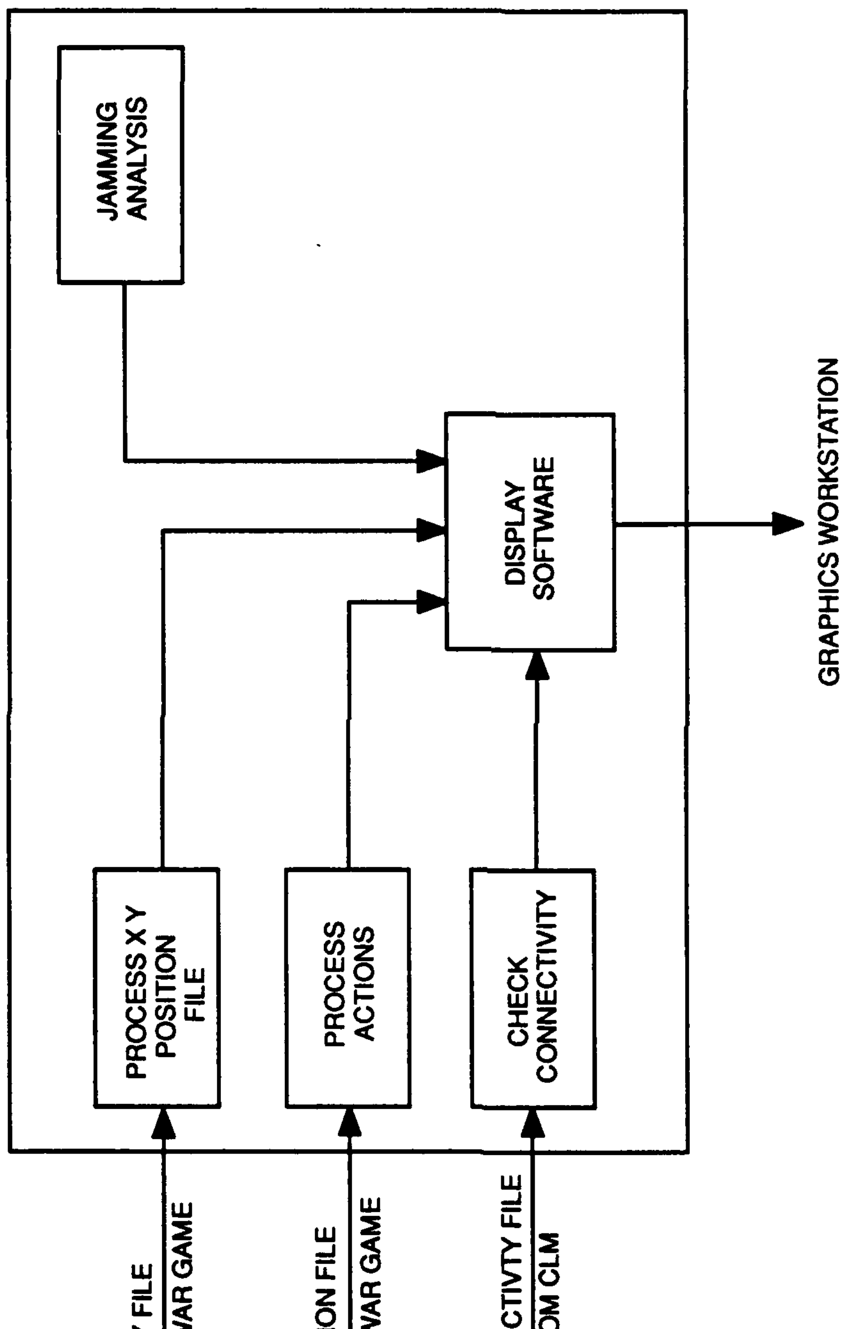


Figure 8. Graphical Analysis Real-Time Mode.

2) Connectivity Plots:

A) A given platform's connectivity with all other platforms in the battle group.

B) The connectivity between participants in a network participation group.

C) Jamming Power/Transmit Signal Power contours showing the resistance to jamming and the ability of a given platform to transmit and be heard by other platforms in the presence of enemy jamming equipment. Contour boundaries can be set to study the effect of different jamming threshold values. Various resolutions of display can be selected depending on the accuracy needed, and multiple contours can be displayed for transmitter-to-receiver link analysis.

For the proper operation of real-time mode, the actions file from the WGM must be further processed by the EMTM, the LCM, and the CLM.

In order to facilitate faster throughput for communication analysis of a scenario, the freeze-time mode has been provided, as illustrated in Figure 9. No additional files other than those provided by the war game are needed.

The platforms' movement directives are shown as the war game proceeds; however, the display must be "frozen in time for the above features to be utilized. Additional capabilities available in this mode are as follows:

1) The effect of assigning a single or multiple platforms to relay incoming message types to additional platforms can be studied and the effects on the communication network analyzed.

2) Saving of graphical screen data in the form of a snapshot for later study or hard-copy on paper/view-graph material.

3) Loading of previously saved screens for further analysis.

Each of the above capabilities will be demonstrated in the applications section of this report.

NETWORK LOADING ANALYSIS MODULE

The Network Loading Analysis Module (NLAM) is a set of software routines which process the network capacity information generated by the CLM. This module is shown in Figure 10. It is capable of graphically displaying the statistical data of the communications loading present for a specific platform or any group of platforms. From the CLM, the NLAM obtains the time a message type is transmitted, the specific message type transmitted, the transmitting platform, the network participation group, and the loading performance of that NPG. The module can generate graphical plots which demonstrate the performance of a given platform, and NPG, or the network as a whole.

One such plot is the trending display, where a JTIDS frame, defined to be 12 seconds, is slid forward in time, and the message traffic within that frame is statistically analyzed and displayed. A static histogram is also available which can show the overall performance at a glance.

Finally, the amount of delay introduced into the communications system due to a lack of message transmission capacity for a given message type, NPG, or platform can also be displayed.

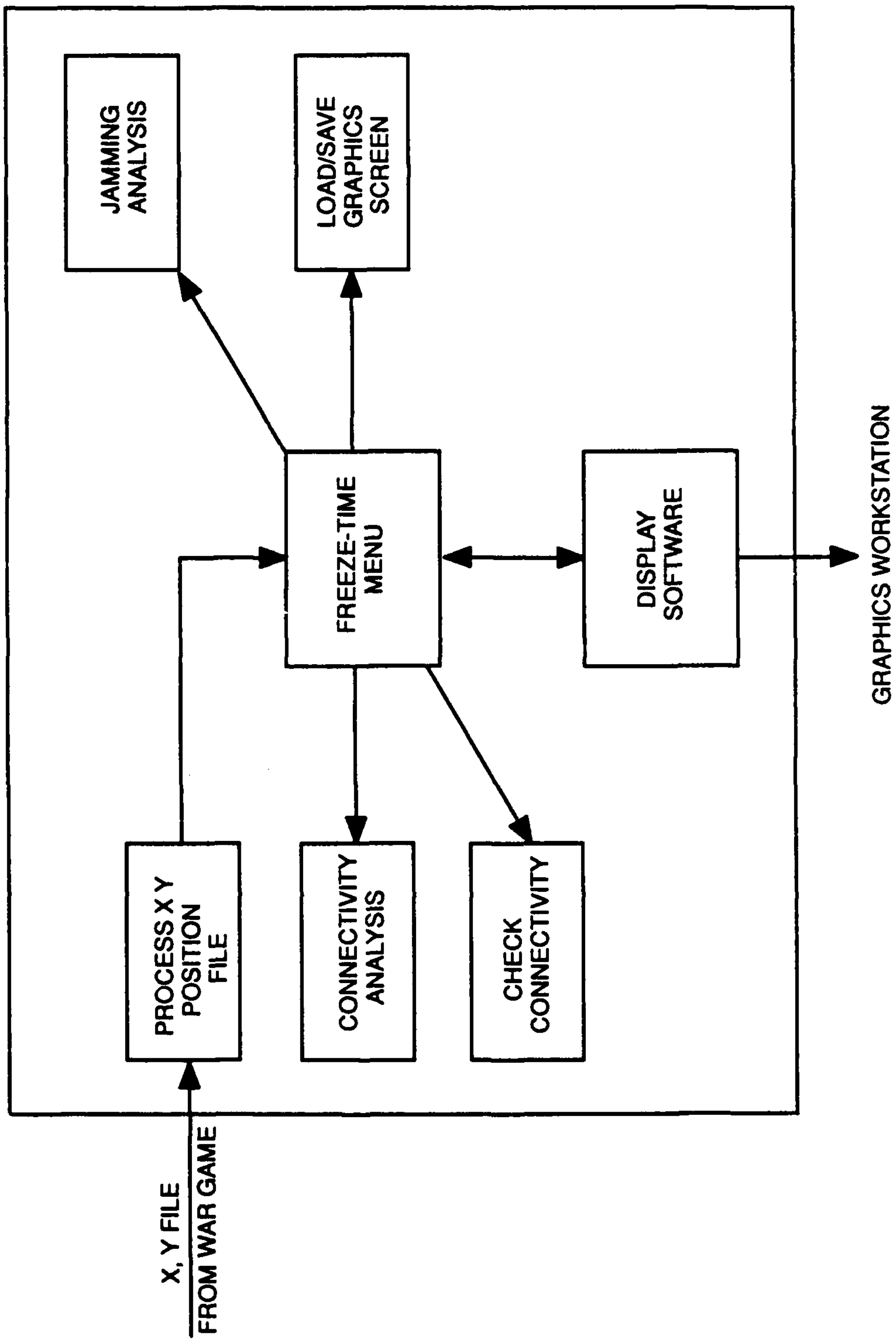


Figure 9. Graphical Analysis Freeze-Time Mode.

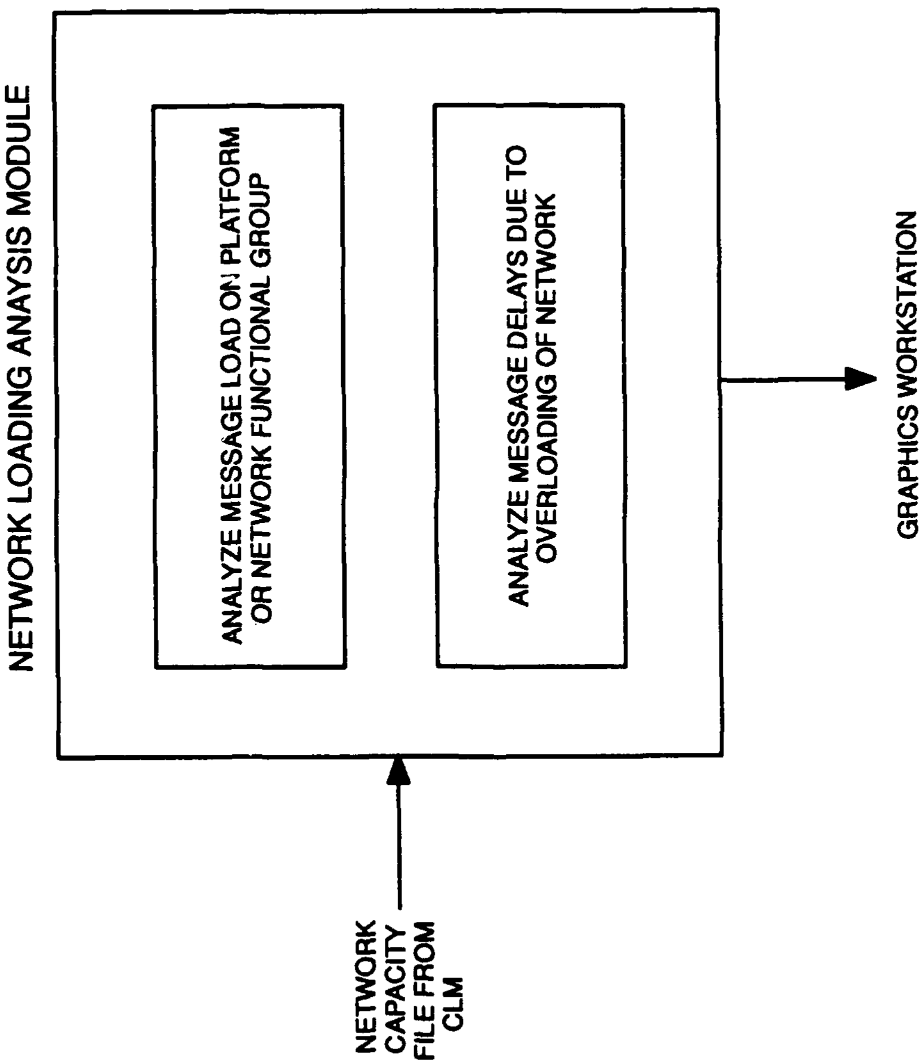


Figure 10. Network Loading Analysis Module.

APPLICATIONS

Current applications of the CNAT include the following:

A) Analysis of jamming effects on communication connectivity

B) Communication network performance evaluation under various loading conditions

C) Analysis of relay platforms to improve communication connectivity

The following pictures are representative of screen images from the graphics workstation demonstrating these applications:

Figure 11 shows a typical scenario at zero game time, or at the start of the game. As the display proceeds, the software time-steps through the x-y position file generated by the war game and each platform will be placed in its new position. Figure 12 is a close-up view of the friendly battle group configuration.

Figure 13 demonstrates several war game actions occurring, in particular, a radar detection and the resulting vectoring of intercept aircraft to investigate by the controlling aircraft. These radar detections are shown as blue lines from the detector to the potential target, and the orange lines indicate the air controllers vectoring of the intercept aircraft.

Figure 14 illustrates the communication connectivity between the E-2C air controllers and the intercept aircraft under their control. The blue lines represent connected paths from transmitter to receiver and the red lines show a disconnected path due to jamming, line-of -sight problems, or insufficient transmit power to reach the receiver. The orange lines indicate the presence of one-way communication from the E-2C aircraft to the receiving platform.

Figure 15 shows the capability to improve the connectivity between platforms by assigning a relay function to each platform within a given network participation group. In this example, each of the F-14 aircraft have the ability to relay any given message to any other F-14 within the network group. It is shown that the communication connectivity has been improved from that of Figure 14.

Figure 16 is an example showing the connectivity of a given platform, in this case an E-2C aircraft, with all other platforms within the battle group.

Figure 17 is a plot of a jamming contour showing the area around an E-2C that a given platform will be able to receive communication traffic. The area outside of the oval is the region where the jammer power is sufficient to block communications from the E–2C to a potential receiver. It should be noted that this particular contour has been drawn at the current altitude of the transmitter. The lines of connectivity, as explained above, are also shown as an additional aid in analyzing the ability of E-2C to communicate information in the presence of a jamming threat.

Figure 18 shows the jamming contour of both the E-2C as the transmitter and an F-14 as a receiver. The ability for a two-way communication link should be seen by the overlap of the two contours. In this case, however, there is no connectivity as can be clearly seen by the lack of any overlap. The outer edge of the contour in this picture shows what the additional coverage of the E-2C would be if his jamming threshold would or could be increased.

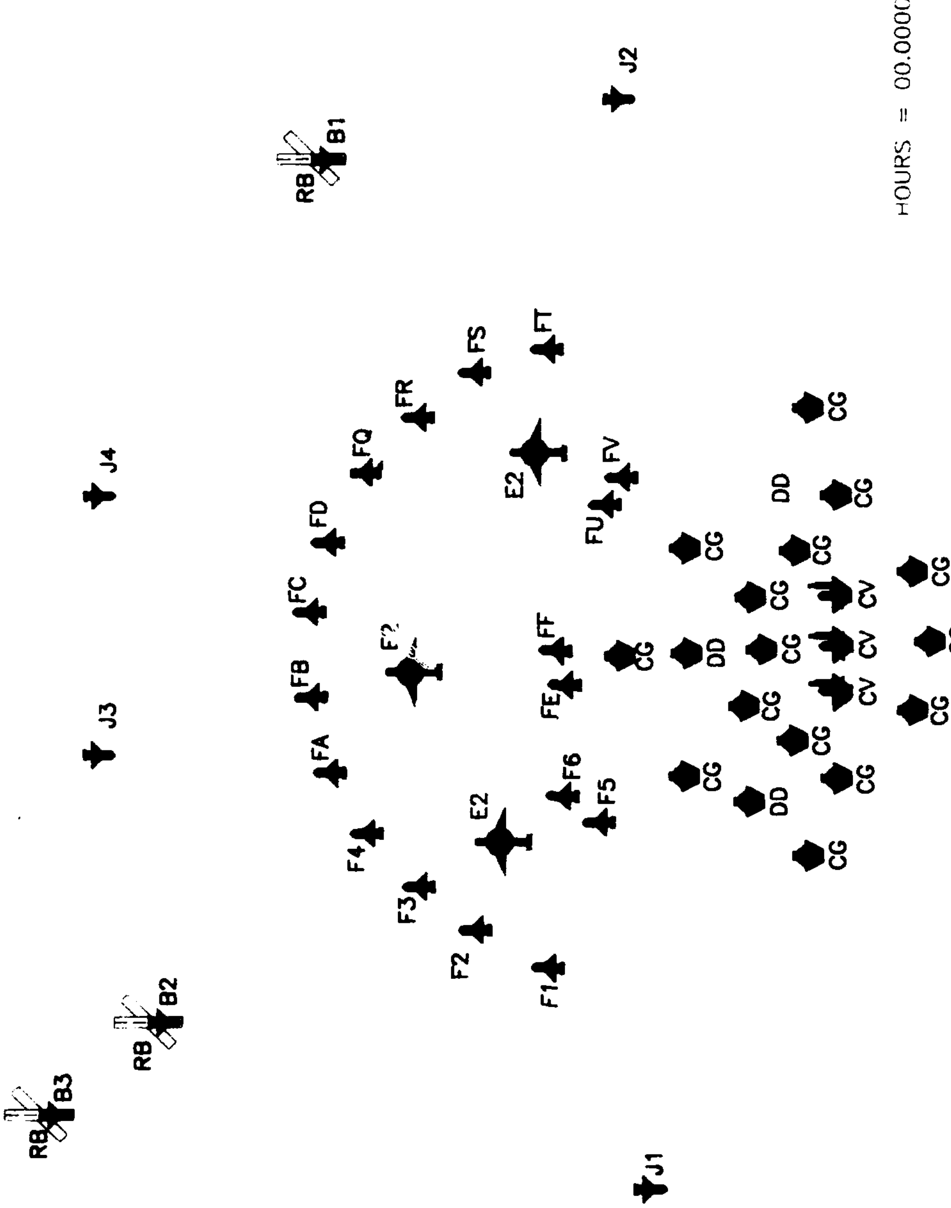


Figure 11. Scenario at Zero Game Time.

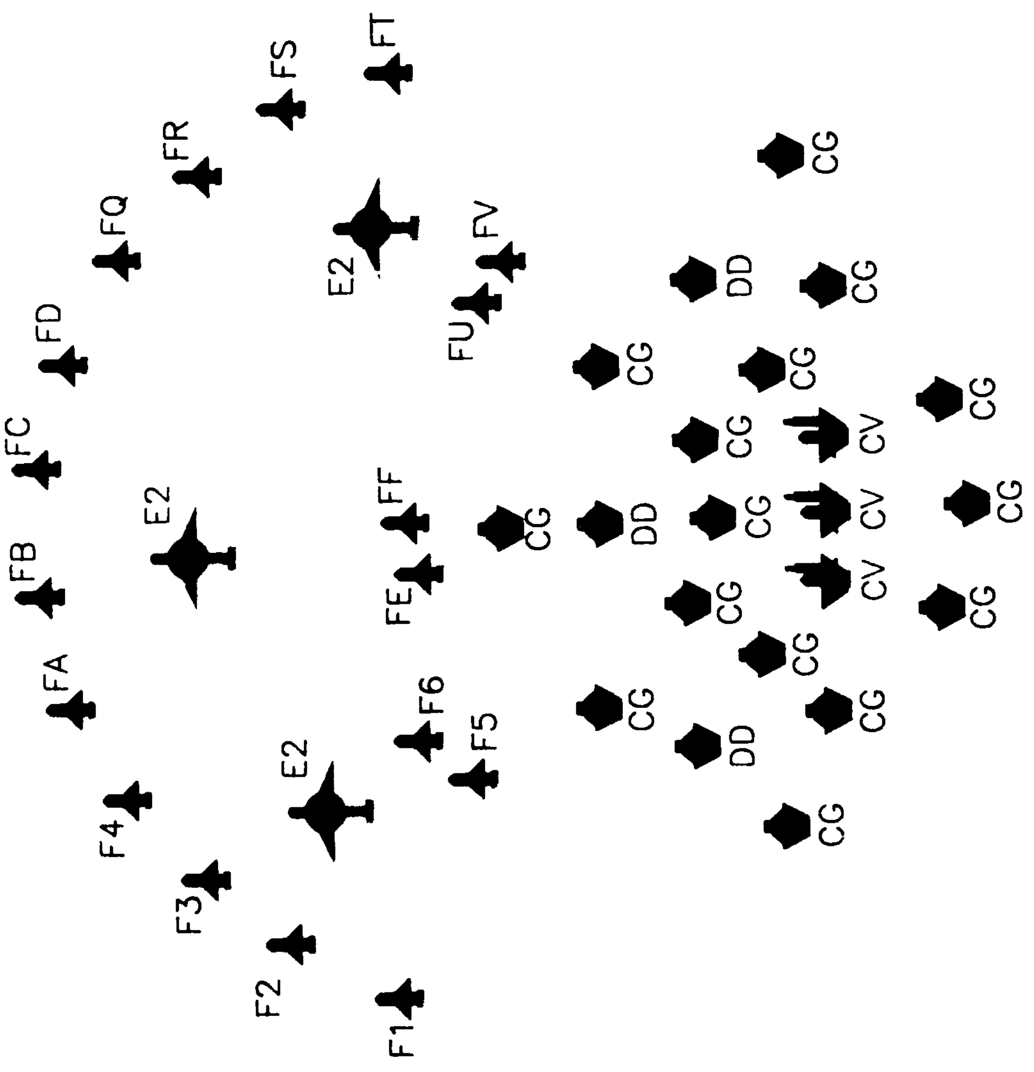


Figure 12. Battle Group Configuration.

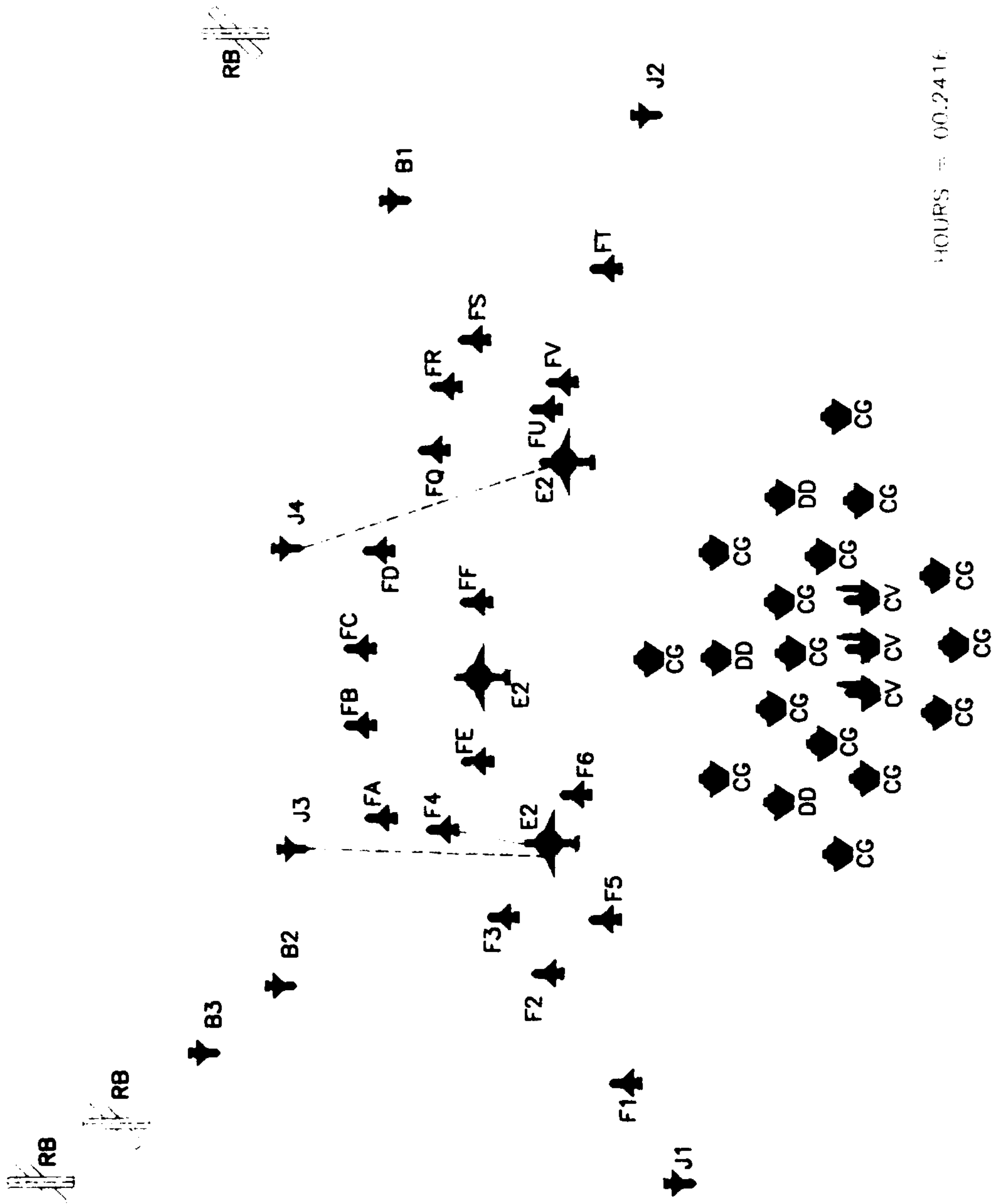


Figure 13. War Game Action (Detection and Vectoring).

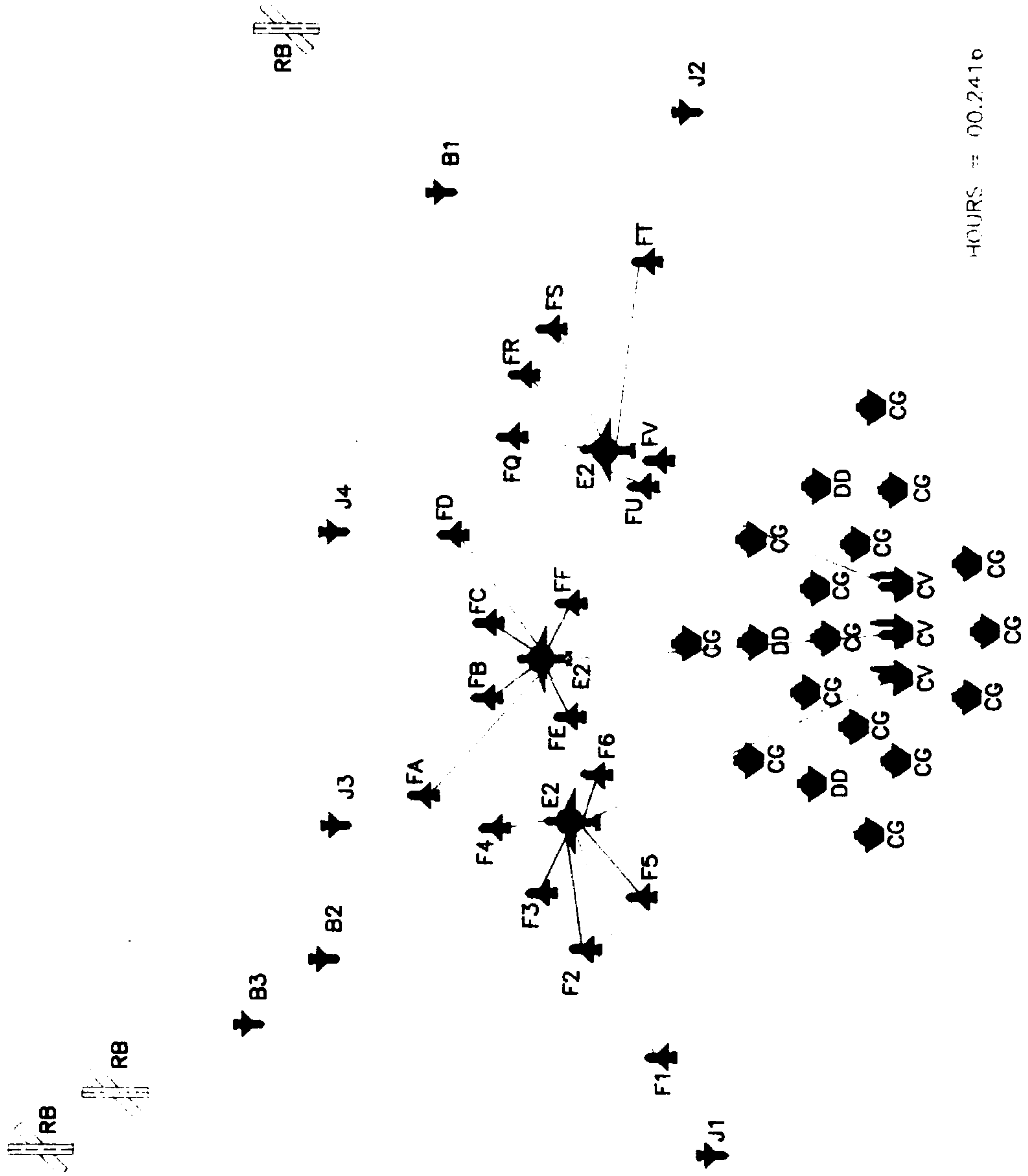


Figure 14. Communication Connectivity.

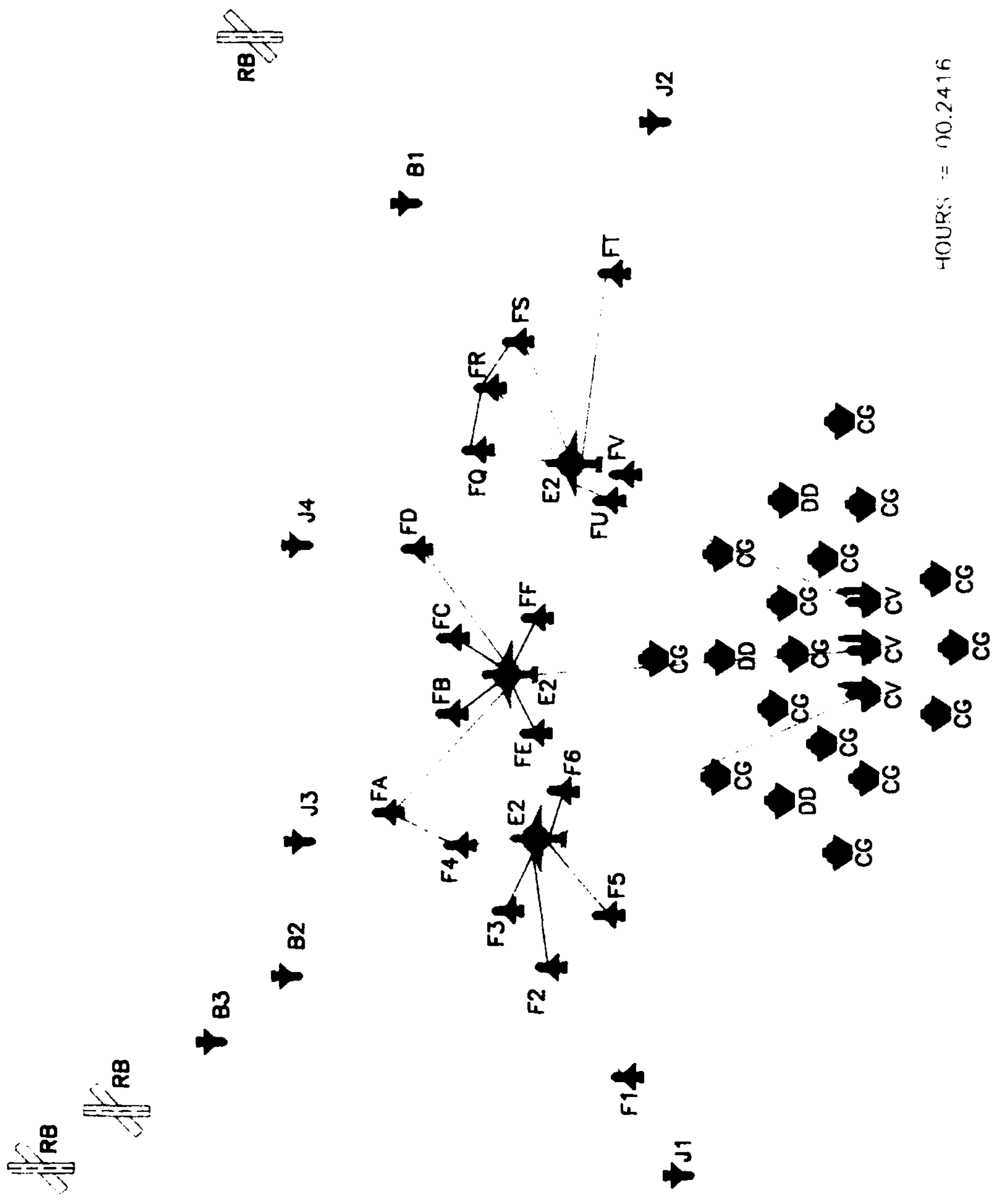


Figure 15. Communication Connectivity Utilizing Relay Platforms.

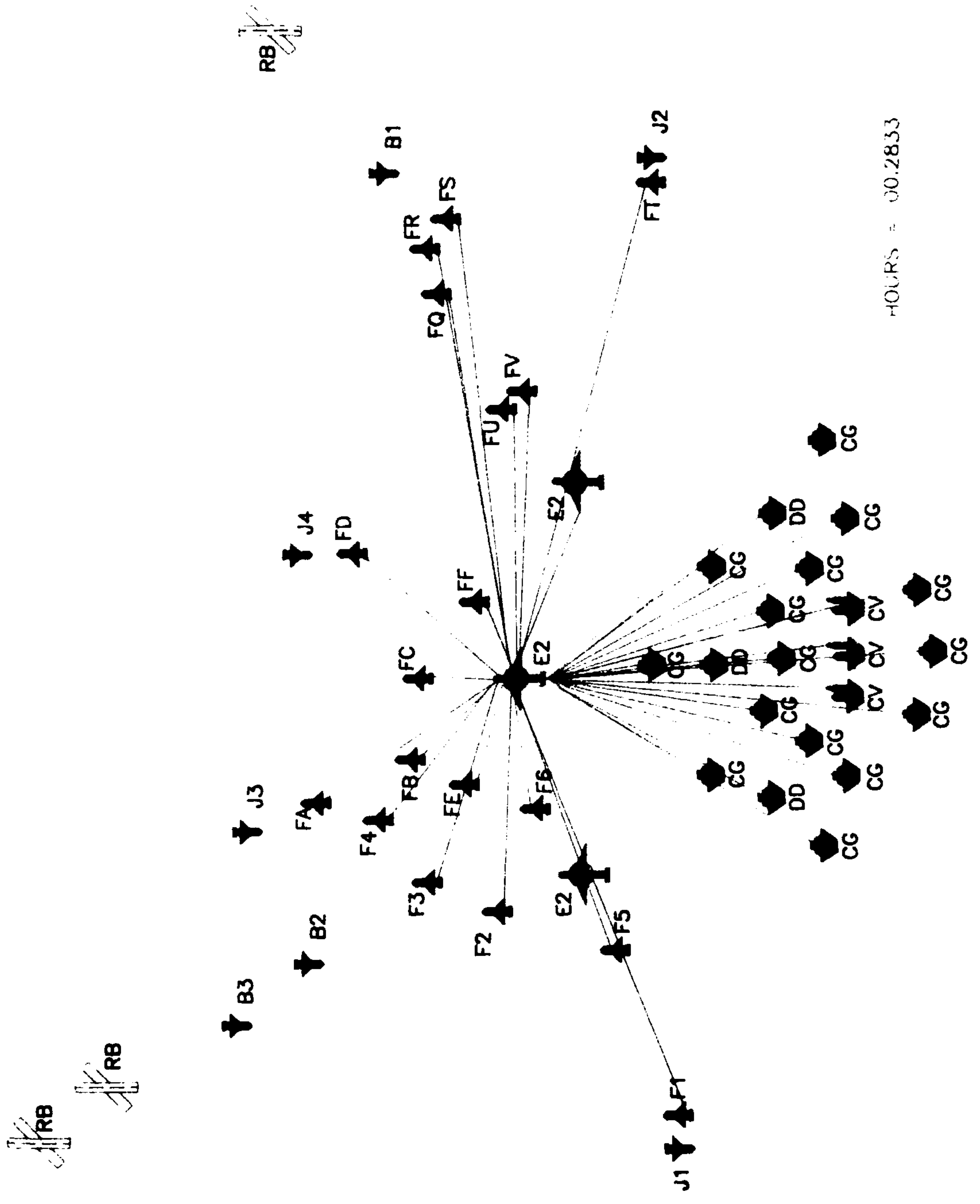


Figure 16. E-2C Communication Connectivity.

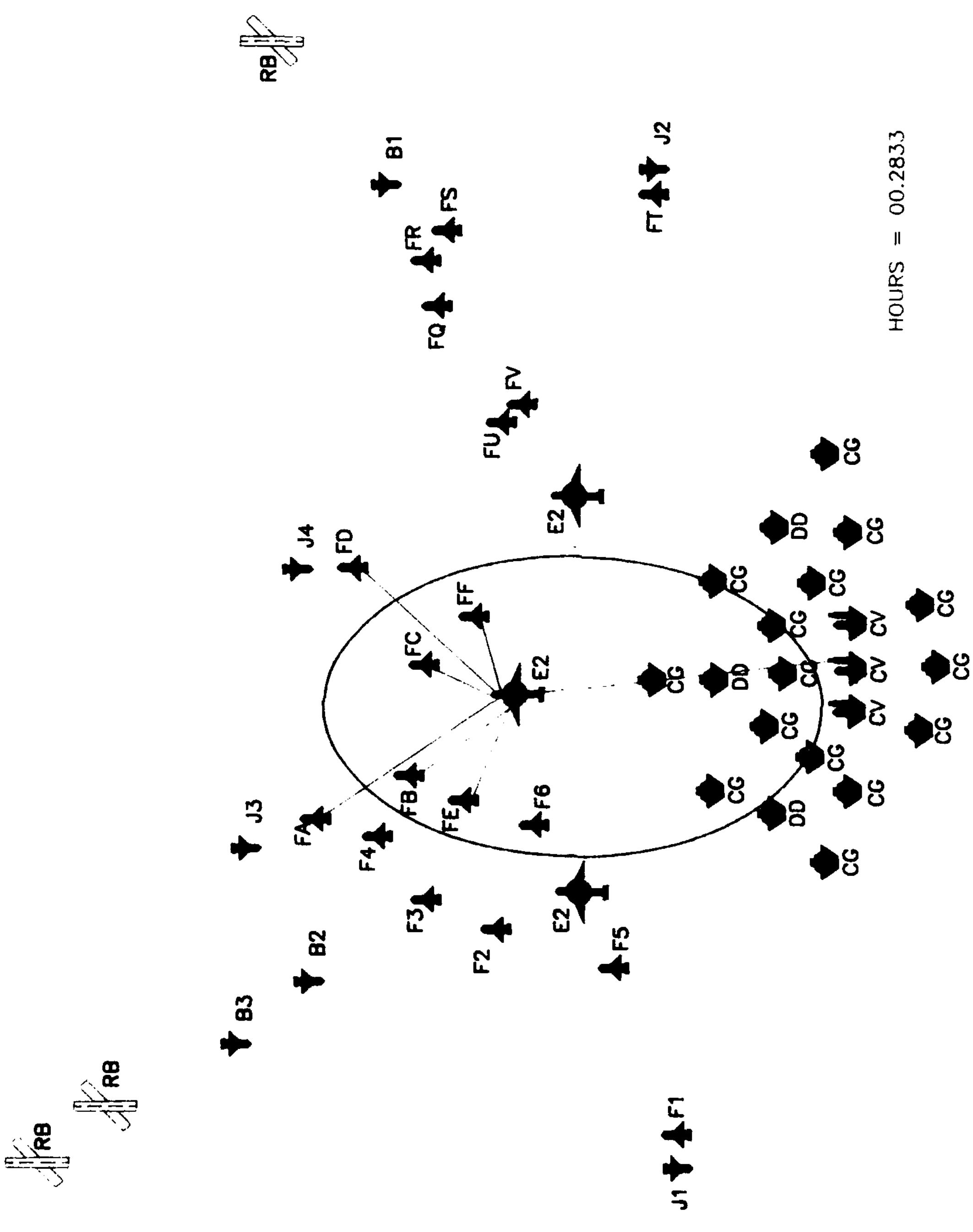


Figure 17. E-2C Jamming Contour.

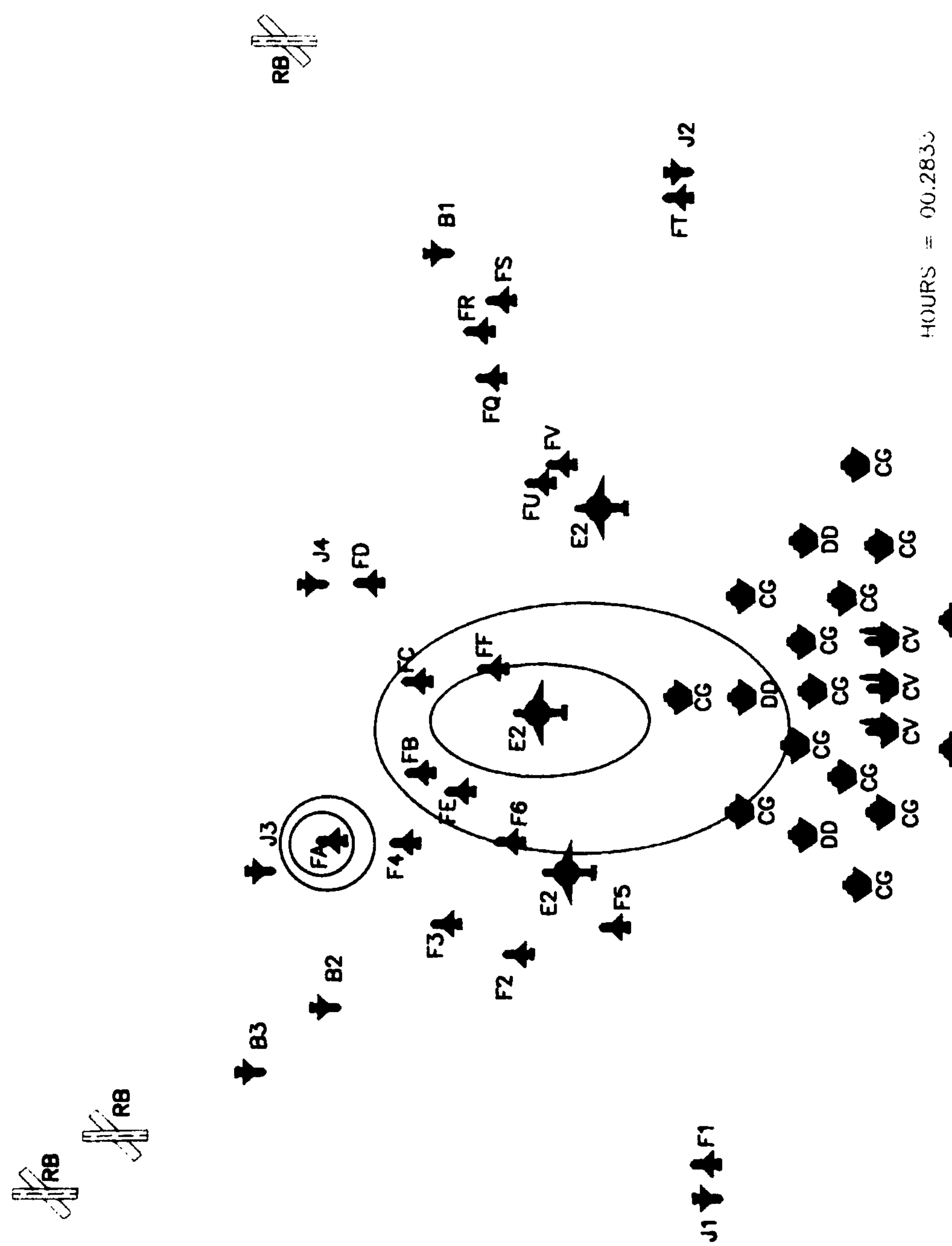


Figure 18. E-2C/F-14 Jamming Contour.

Figure 19 illustrates the ability of the NLAM to show the message loading of a particular function such as surveillance. The loading in terms of radar tracks is shown plotted during the time interval of the scenario. The upward slopes of the curve are due to detection of incoming raids of enemy bombers. The downward slopes are due to the destruction or loss of detection of the enemy aircraft. When the graph crosses the maximum tracks within NPG line, the system capability of the NPG has been exceeded. The communications traffic necessary to support the surveillance function can no longer be handled within one transmit frame of the communications system, and will therefore be delayed until the next available transmission opportunity.

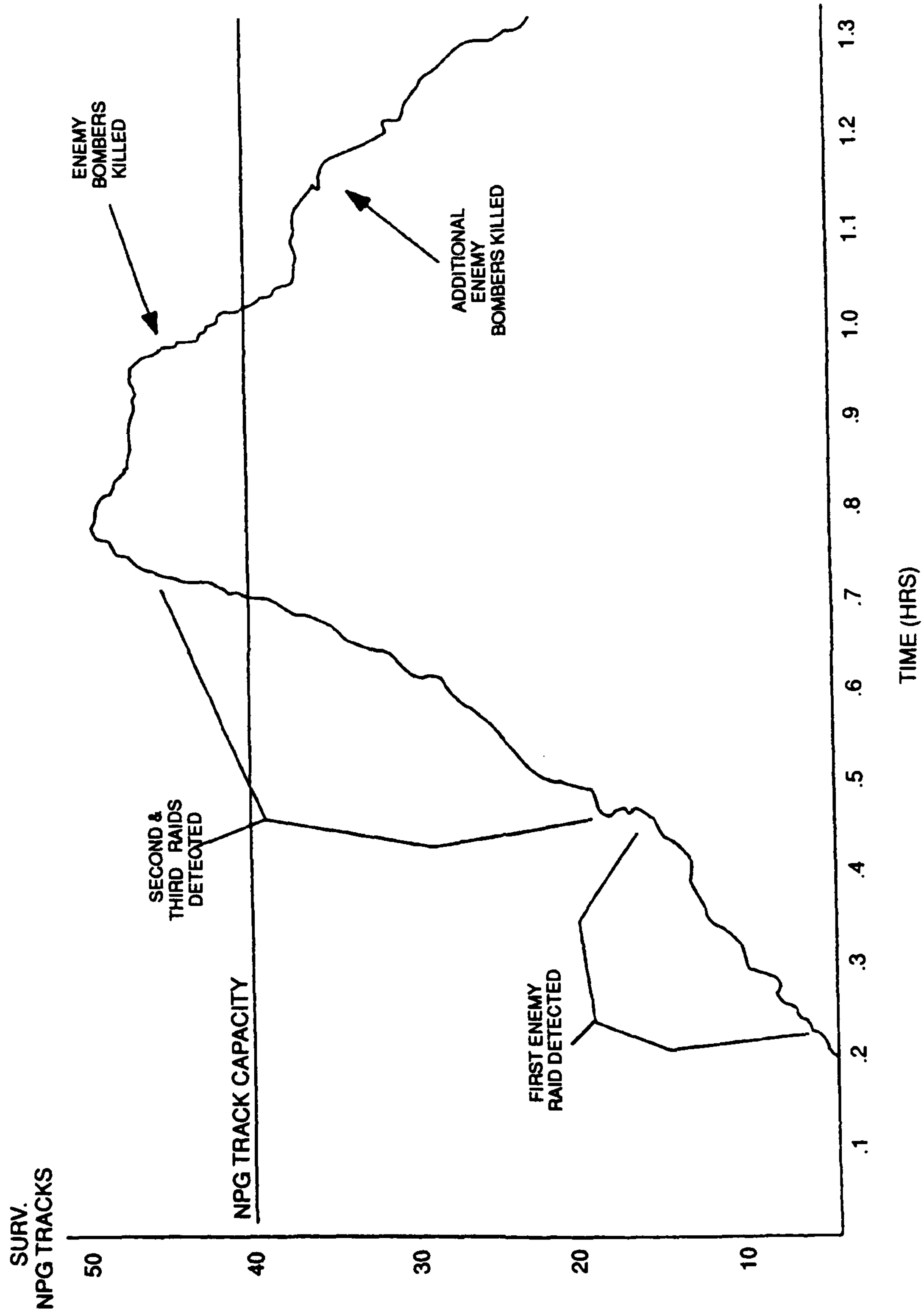


Figure 19. Network Loading Analysis.

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